HELIX PEDESTRIAN BRIDGE

By David McMullen and Michael Blank

The Helix Pedestrian Bridge is an icon for the biotechnology industry and its patron Amgen. It is a transformation of basic biological structures of DNA into a rational engineering design that is a major pathway to work each day for employees of Amgen, and provides a safe public route to reach the waterfront. The 420 foot long walkway spans 11 active railway lines and connects Elliott Avenue, a major Seattle thoroughfare, to the new campus. Amgen's goals for the project were to provide easy access to public transportation for their employees, and to support the local community by enhancing public access to the waterfront park.

Creating a signature bridge can take two basic paths. The story of the structure can be told by applying artistic components to a common structure, or the structure itself can become the statement. As the design team brainstormed concepts for the bridge, an underlying theme developed that built upon Amgen's biotechnology core values. The structure itself became the vision through its helical form. A common misconception is that signature bridges must be expensive. If the architectural treatments are stripped away from the Helix Bridge, the basic "bones" of the structure make up only half of the overall costs. And the "bones" in this case are the story.

Conceptual Design

The Helix design concept was an interactive process that involved the structural engineer, architect, and owner. During early design sessions, design concepts were brought to life by forming foam, wire and clay into small-scale bridge models. Many of the design concepts were based upon the helical structure of DNA, the building blocks of life that Amgen works with everyday. The structural engineers then performed preliminary analysis on over two dozen design concepts to determine their structural feasibility. The team unanimously chose the three-arch system as the final design.

The bridge structure consists of three steel pipe arches. The center 36-inch diameter arch spans 420 feet from the south side of the bridge on the west end, crossing the deck to the north side of the bridge on the east end. At its highest point, it is 60 feet above the railroad tracks. Each of the two 24-inch diameter side arches span from the end of the bridge to a concealed at-grade pier in the center of the bridge. These two side arches taper and cross at the center pier, and are canted approximately 30-degrees from vertical.

The deck truss acts like a diaphragm to transfer lateral loads to the elevators and side arches. It is supported from the arches by means of steel trusses made of structural steel tube sections. A stainless steel mesh system, that required openings to be limited to less than 2 inches, was installed to meet the railroad's requirements when the deck is above the tracks.

The design impulse load used due to the footfall of pedestrians resembled that of two camel humps. The impulse loads were applied to nodes along the deck at 2.5-foot intervals. The impulse frequency was varied in order to capture people walking slow and fast. We started with three people walking from one end of the bridge to the other. This was then increased to groups of people walking across the bridge. The laterally applied load was 10 percent of the vertically applied load at half the frequency. Neither the vertical or lateral loads excite the bridge to a point that would make people uncomfortable.

A post-construction vibration analysis is currently being performed. Preliminary tests on the deck indicated that the damping of the deck structure is between 4 to 5 percent.

Design Code Application

The helical bridge structure does not fit a typical bridge model. Nor does it fit a typical building model. The unique architectural treatments – a fabric roof, large mesh enclosures and elevators – created the need to mix the use of available design codes. General code guidelines needed to be defined to allow the City to review the project and issue a building permit. It was decided that the bridge would be designed using parts of the UBC, parts of AASHTO's bridge specifications, the Seattle Building Code and parts of the Ontario bridge specification.

Wind Loading

Not surprisingly, the dynamics of the structure are extremely critical due to the pedestrian use. Mesh and fabric, which partially enclose the majority of the bridge deck, made wind design the critical lateral load case. The large sail-like effect of the mesh made the wind loading condition greater than the earthquake loading condition, an unusual occurance for a bridge in seismic zone 3.

Flexibility of the deck and its sensitivity to wind was handled in a number of ways. Though the deck appears very slim, it meets the standard limits of depth-to-span and length-to-depth ratios. Another component of the bridge is the vertical trusses. These members provide a stiffness not typically found in a cable or rod-type vertical hanger, and more like a space truss structure. An additional key consideration was to design a deck that was not sensitive to flutter. This was accomplished by limiting the span length-to-depth ratio.

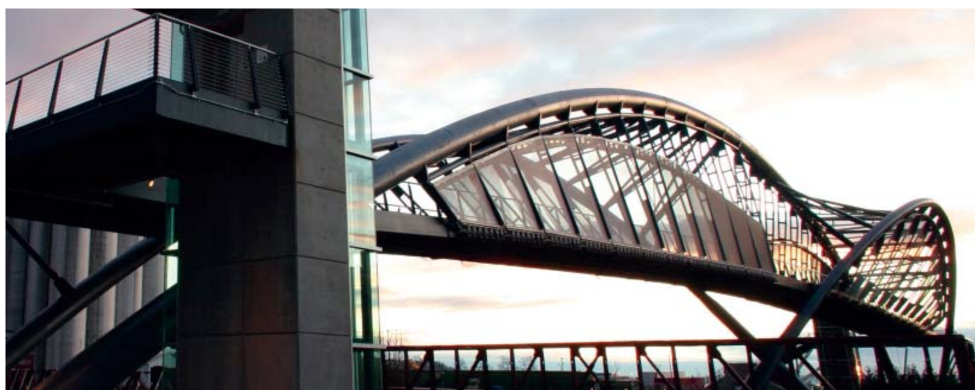
Human Induced Vibrations

Due to the asymmetric shape of the structure and canted arches, both vertical and lateral forces induced by pedestrians were fully analyzed. The design team used the Ontario bridge code and the experiences shared by others in the industry to model the pedestrian live load.

The structure was first designed due to static pedestrian loads. A distributed load of 85 pounds per square foot was applied to the entire deck in a variety of patterned loading conditions. Once the structural geometry and member sizes were determined due to static pedestrian loads, wind loads, self-weight and seismic loading, the structure then was loaded with simple dynamic time history pedestrian loading. The goal was to estimate the accelerations due to a variety of groups of people walking across the bridge.

Geotechnical Analysis and Foundations

The foundations of the Helix Pedestrian Bridge received special attention during the design due to the unique needs of the project. The presence of the railway lines and right-of-way concerns made it impractical to tie the arches of the bridge. As a result, the primary structure of the bridge is an untied arch. The large thrust created by the arches at the bridge abutments is resisted by lateral resistance of the pile foundations. Foundation movement was a critical concern during the design and construction due to the flatness of the arch and the geometric sensitivity of the arch to foundation movement.



Lateral load tests were conducted on the auger-cast piles to determine load-deflection characteristics of the soil under cyclic loading and vibrations from trains. The tests were performed by jacking between two piles. Deflections were then measured by dial gauges. The load applied was approximately 155 percent of the allowable design load. Measured deflections were 0.14-inches. Unloading and reloading the pile had relative little change in the deflections. No deflection movement was registered while trains were passing the site. The gauge only measured 0.001-inch movement with pile driving taking place within 200-feet of the pile.

The original analysis predicted a 0.5-inch deflection at a little less than the actually applied load. The lateral test results were 0.15-inch. This illustrates the conservatism built into the default P-Y curves of the Lpile software used.

Aesthetics

There are a variety of aesthetic components to the Helix Bridge, the most striking being the geometry of the bridge form itself. As one walks along the deck, the structure gives the allusion of twisting around the visitor. More subtle components are the new view opportunities of the downtown skyline, Olympic Mountains and Elliott Bay. The natural forms and openness of the bridge make it highly compatible with its environment on the Seattle waterfront, and with the expansive views of Puget Sound, Mount Rainier, and the Olympic Mountains. To minimize obstructing views, the bridge has a low profile and relatively flat arches. As the population increases and available living space diminishes, access to scenic views and parks will become even more important. The architect sited the bridge carefully to frame the views of the water and city skyline. The Helix Bridge allows local neighbors to cross the railroad tracks safely, and expand their “front yards” to the waterfront park on the other side.

Lighting was another creative aspect of the project. Lighting is required for public safety, along with enhancing the bridge’s statement at night. However, the lighting could not adversely affect the railroad engineers nor be visible by residents of the neighborhood up the hill from the site. To address this issue, strip lighting was embedded in the handrail stanchions and above the mullion for the vertical trusses. Meanwhile, a tension fabric membrane diffuses the light and reduces the visual impact to the neighborhood.

Fabrication and Construction

AMEC Dynamic Structures (ADS) fabricated and erected the steel portions of the bridge. They were faced with very tight fabrication and erection tolerances due to the complex geometry and aesthetic nature of the structure. It was necessary to fabricate the arches to a complex cambered shape in order to achieve the final geometry specified. Since the side arches are canted, or inclined, gravity causes substantial out-of-plane bending of the arches. To counteract the out-of-plane bending, the arches were fabricated with “three-dimensional” camber. Approximately 20 different finite element models were created, each corresponding to a different partially erected configuration of the bridge in order to estimate the camber and accurately calculate member connections. The arch sections were generally bent to within ½ inch of the required idealized geometry, while the overall bridge was within ½ inch of its intended geometry over its entire 420-foot length.

Given the extensive site access limitations created by the multiple railroad tracks, there was little space available to shore the bridge structure during construction. A unique system of erection equipment, consisting of traditional falsework structures, cable stays and a rotating falsework tower, was used to install the deck and arches. Extensive provisions for adjusting the position of the deck and arch sections were built into the erection system. Six falsework towers were used: one at the center pier and the remainder near the ends of the bridge. The falsework towers each included a system of adjustable arch cradles and adjustable bridge deck support stools. A specially designed rotating mast was mounted on the center falsework tower. A key part of the erection procedure was to rotate the center arch infill segment from a position parallel to the railway lines to its final position nearly perpendicular to the railway. The operation was completed in about 20 minutes, without incident and with minimal impact to the train schedules.

Conclusion

The bridge stands today as a testimony to the owner’s vision as well as to the teamwork involved, innovation in bridge design, and creative construction techniques. The bridge combines both form and function to show how an ordinary pedestrian bridge can become an extraordinary statement. The project has won broad community support in the few months that it has been open.

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